POPULAR
SCIENCE
BOOKLET SERIES

THE EARTH'S CRUST

Author: Xie Qicheng
Liu Jingyuan
Translator: Meng Jin

CHINA SCIENCE AND TECHNOLOGY PRESS

FROM THE EDITOR

This small book can serve as a clue to help us in understanding the nature of the earth. With a style both succinct and easy to be understood, it gives us a broad outline of the earth's shape, size chemical compositions, physical structures and the geological processes which sculptured and are sculpturing various landscapes on the earth's surface. It also tells us that the earth provides man with rich minerals that we use to construct our facturies and to drive our automobiles and machines. It is a reading matter particularly suitable for readers having a junior middle school education.

THE EARTH'S CRUST is one of the "Popular Science Booklet Series" which has a total of twelve booklets, namely, Mechanism, Sound, Heat, Electricity, Air and Water, Light, Astronomy, The Earth's Crust, Meteorology, Animal, Plant and Hygiene.

Popular Science Booklet Series

THE EARTH'S CRUST

Author: Xie Qicheng
Liu Jingyuan

Translator: Meng Jin

China Science and Technology Press

First Edition *1985*

Published by CHINA SCIENCE AND
TECHNOLOGY PRESS
32 Baishiqiao Road, Beijing, China
Printed by THE FOREIGN LANGUAGES
PRINTING HOUSE
19 West Chegongzhuang Road, Beijing, China
Distributed by the China International Book Trading
Corporation
(GUOJI SHUDIAN)
P.O. Box 399, Beijing, China
Printed in the People's Republic of China

CONTENTS

CHAPTER I
THE EARTH — THE HOMELAND OF MAN 1

The legend of "a square land and a domed heaven" 1
The size of the earth 4
The interior of the earth 6

CHAPTER II
THE SHELL OF THE EARTH — THE CRUST 11

The diversification of land surface 11
The everchanging crust 15
How does the earth's crust change itself? 18
Plate tectonics 21

CHAPTER III
CATASTROPHE OF THE EARTH — VOLCANOS AND EARTHQUAKES 30

Volcanic activity 30
Earthquakes 37
The distribution of earthquakes and volcanos 47

CHAPTER IV
ROCKS — THE CONSTITUENTS OF THE CRUST 49

Elements, minerals and rocks 49
Igneous rocks 52
Sedimentary rocks 56
Metamorphic rocks 62
A special record of the earth's history 64

CHAPTER V
TREASURES IN THE EARTH — MINERAL RESOURCES 74

Abundance of mineral resources 74
Plant and coal 78
Organisms and oil 81

CHAPTER I

THE EARTH—THE HOMELAND OF MAN

You and I are from the earth. It accommodates us with a vast space in which we do what we can. It provides us the substances that we carry in our bodies. It bestows on us rich resources from which we make our machines and fertilize the soil. The earth permits the existence of human beings.

The legend of "a square land and a domed heaven"

The earth is a globe, but the ancient people did not know the fact simply because their primitive tools could not extend their capabilities so efficiently that they had the power to survey the world. They took a small visible part of the earth as its whole. In their eyes, the earth looked like a smooth land covered by the heaven — a huge bowl upside down. They thought that the earth was square and the sky domed, that the sea and the sky met at their invisible distant edges where was the end of the earth and where nobody had ever visited.

Not until over 2,000 years ago did the ancient come to realize the earth not to be a flat land but to be a globe.

When you see at the beach a ship sailing from far to you, you will first see its mast, then the upper part of the ship, finally the whole body of the ship itself. If the earth is flat you can see not the phenomenon but an entirely different picture that the ship only becomes smaller and smaller as it sails farther and farther away (Fig. 1).

Fig. 1 A ship sailing to you.
Its mast appears before its body does

In the wake of the European Capitalism about four hundred years ago there was a big rush for exploration of new shipping lines. In September of 1519, Magellan, sent by the king of Spain, began to circumnavigate the world for the first time. More than 200 explorers headed by Magellan set out in five ships from Spain, crossed the Atlantic westwards and rounded the southern Africa, to search for the *terra incognita.* During the voyage out they met many unbearable difficulties. They drank dirty water, fed on scraps of wood and even mice. In March of 1521 they reached the Philippines where Magellan was killed tragically in a fight with the natives. Some of Magellan's men escaped from the fight. They kept on going and after three years of experience of hardship came back the port of departure by way of the Indian Ocean and The Cape, with only one ship and eighteen men survived.

It is the first time in the recorded history of man that people had succeeded in taking a voyage round the world. This voyage convinced people that the earth is really a globe. From then on, more voyages round the world were made to explore every corner of the earth, by seas, by land and by air, which all further confirmed that the earth is a globe.

With the development of science and technology, such as the successful launching of man-made satellites and spaceships, very perfect photos showing true form of the earth have been taken, enabling us to have a full view of the face of the earth (Fig. 2).

Fig. 2 Satellite photo of the earth

The size of the earth

After the concept of the earth as a globe was generally accepted, people have described the shape of the earth as a ball, an ellipsoid, an orange or a pear. Measurement and calculation show that the earth is by and large an ellipsoid with a shorter radius, the polar radius, about 6,356.76 km from the center of the earth to either of the South Pole or the North Pole, and with a longer radius, the equatorial radius, about 6,378.16 km. from the center to the equator (Fig. 3). In addition,

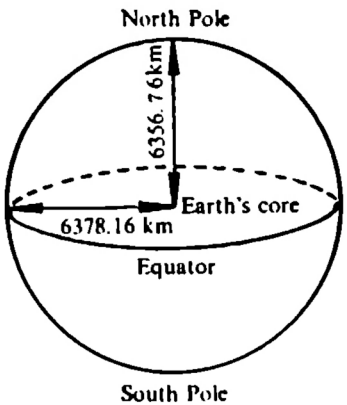


Fig. 3 The equatorial and the polar radius of the earth

the equator itself is not an exact circle. The difference between the long radius and the short one of the equator is 212 m. Such an ellipsoid with a long and a short equatorial radius and a polar radius, different one another, is called a three-pole ellipsoid (Fig. 4).

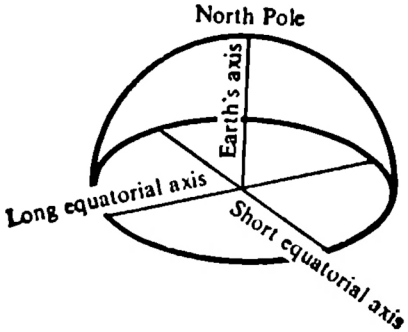


Fig. 4 A three-pole ellipsoid

More precise measurement from man-made satellites brought it to light that Southern and Northern Semisphere of the earth divided by the equator-plane are not symmetric: the northern one slender and longer and the southern one a little wider and shorter; the north polar radius is 40 m longer than the south one (sea level as the standard). So the earth is an irregular ellipsoid (Fig. 5). It looks like a ball, but in fact an irregular ellipsoid of 1/300 flattening. Imaginatively, it looks like a volleyball pressed slightly between your hands.

The mean radius of the earth is about 6,371 km and the greatest circumference is 40 thousand km. It will take us about three years and eight months to travel (if on foot) round the earth at a speed of 30 km per day, and take even 40 hours by aeroplane at a speed of 1,000 km per hour. The surface area of the earth measures 5.1×10^{8} km^2, 52 times larger than that of China; its volume about 1,080 billion km^3 and its weight 5.98×10^{21} tons. What a giant it is! However, it is

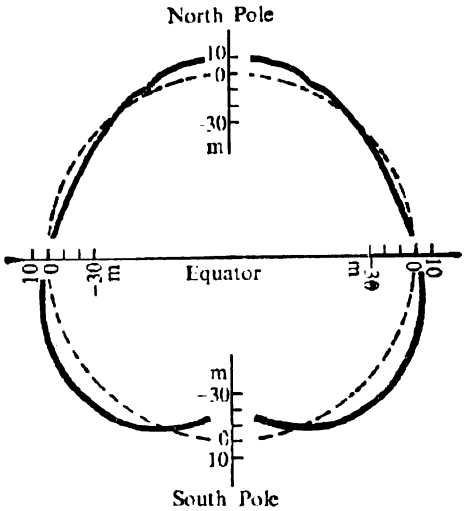


Fig. 5 The ellipsoid and the earth's standard surface

nothing but a drop of water in the blue sea — the boundless universe (Fig. 6).

The interior of the earth

What does the interior of the earth look like? At present it is impossible to have an immediate observation of it. The deepest drill reached a depth of 10,000 m or so, penetrating only a very thin layer of the earth's crust, not deep enough to get sample furnishing information of the internal structure of the earth. By studying the materials emitted during an eruption of volcano and the waves of natural and artificial earthquakes, scientists come to the conclusion about the chemical and physi-

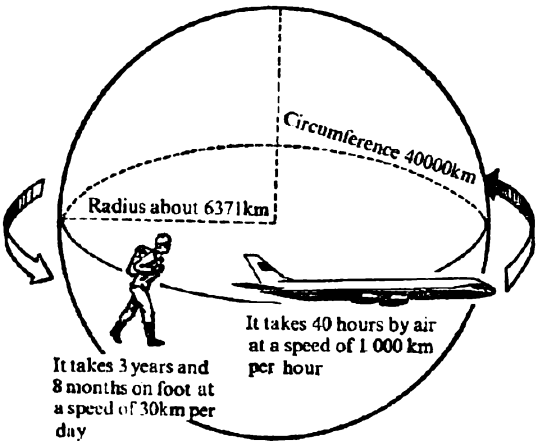

Circumference 40000km
Radius about 6371km
It takes 40 hours by air at a speed of 1 000 km per hour
It takes 3 years and 8 months on foot at a speed of 30km per day

Fig. 6 The size of the earth

cal natures of the interior that from the surface to the center of the earth there are three layers, of which the outer layer is the earth's crust, the core is the earth's core, and between them the mantle (Fig. 7).

The natures and compositions of the three layers are different one another. Generally the greater the depth is, the greater the density is, and the higher the pressure and the temperature are.

The earth's crust, a hard "skin" of the earth, ranging some 16 km in thickness on an average, is composed of various rocks different in their chemical compositions and natures. The crustal thickness varies widely and abruptly from region to region. The oceanic crust is the thinest, only five to eight km thick in some parts; under mountains or plateaus the crust may extend to 80 km thick at most; under

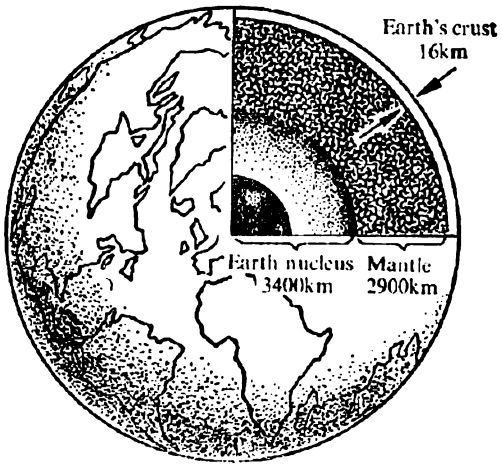


Fig. 7 The internal structure of the earth

plain and shallow sea the crust is of a middle thickness (Fig. 8).

The oceanic crust is mainly composed of basalt which is rich in silica, magnesium and iron. This layer of the crust is

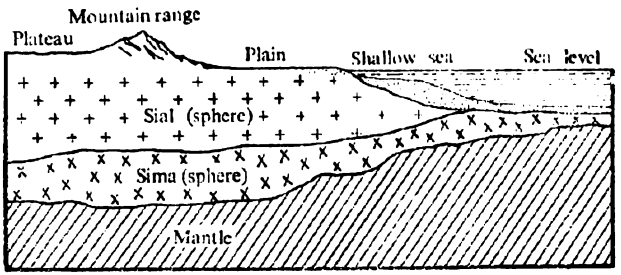


Fig. 8 A sketch to show the thicknesses of oceanic and continental crusts

referred to as sima. The continental crust (including the marginal areas of continents) consists of two layers: the upper layer named sial, chiefly consisting of granite, rich in silica and aluminium, but lighter than the underlying layer — the sima, which is usually thinner. Between the two layers exists a discrete boundary called Conrad Discontinuity that causes the velocity of earthquake waves to change.

The mantle extends from the base of the crust to the boundary between mantle and earth's core, i.e., from 17 km down to 2,900 km on an average. From the depth of 650 km upwards is the upper mantle. The upper part of the upper mantle, ranging about 50 km from the base of the crust downwards, is the rigid lithosphere. Because of a high temperature caused by decay of radioactive elements, the mantle material in the range from 50 to 250 km beneath the lithosphere is in a melted-state or partially melted-state. This weak layer is the asthenosphere where is the birthplace of magma. From the lithosphere to the asthenosphere no boundary is sharply defined. Between the crust and the lithosphere lies the famous Mohorovicic Discontinuity through which earthquake waves will abruptly change their velocity. The temperature varies from 1,200 to 1,500 centigrade and the pressure is about 500 thousand atmosphere in the upper mantle. The lower mantle is from 650 km down to 2,900 km, in which temperature and pressure are even higher. The conditions of the lower mantle and the lowest part of the upper mantle are little-known. We extrapolate from the composition of aerolite that perhaps exist some much denser oxides and silicates containing iron and magnesium.

Beneath the mantle is the earth's core that can also be divided into two layers: the outer core, supposed to be liquid, and the inner core, perhaps solid. Still we find a boundary between the core and the mantle, called Gutenberg Discontinuity which again affects the velocity of earthquake waves.

Why are the earth spherically layered? What the devil are the internal materials of the earth? Why does the density of material increases as it descends towards the core? Although man has been looking for solution, no unanimously agreed answers have been gained up to now. No doubt, with the further development of sciences and technology in the future the keys to the puzzles will surely be found.

CHAPTER II

THE SHELL OF THE EARTH— THE CRUST

The diversification of land surface

The crust is a very thin shell that is to the earth is as much as eggshell to an egg. Nevertheless, the surface of the earth, unlike glossy eggshell, rises and falls irregularly, exhibiting various landscapes. It is on the very thin crust that live over four billion people who seize prize after prize from it. The area of the oceans is about 361 million km^2 which covers the most, about 71%, of the earth's surface, whereas that of the continents is only 149 million km^2, 29% of the total. In short, the earth's surface is shared by oceans and continents at the proportion of seven to three.

The extreme height of the land is Jolmo Lungma or the "Mount Everest", the highest peak in the Himalayas on the border of China and Nepal, at an altitude of 8,848.13 m above sea level. The Dead Sea between Jordan and Palestine is the lowest, 392 m below sea level. Here and there on the dry land there are lofty and steep ridges and peaks as well as wide and extensive fields. According to different height and

topographic features, five topographic units can be distinguished on the earth's surface: plain, plateau, basin, hill and mountain. They are arranged in complex crisscross patterns, which depict the rugged rough landscape on the earth's face.

Seafloors concealed under the boundless oceans are not flat either. Submarine topography varies to a greater extent than that of the dry land. Seafloors are composed of, roughly, three major units: continental shelf, continental slope and ocean floor. Continental shelf is the extension of continent under the sea, with a minor slope and at the depth of 200 to 300 m. Its geological structures are very similar to that of the continent. Thanks to the sun rays penetrating the water, marine plants flourish and aquatic animals crowd in the shallow sea near the coasts. The offshore oil fields have been first exploited because of the favorable conditions for drilling and transportation of oil. From the shelf seawards, depth and gradient of the seafloor increase sharply. The steep slope is continental slope which is the transitional zone between continental shelf and the ocean basin floor. The very boundary between continent and ocean lies just at the bottom of the continental slope. The ocean floors are the main part of oceanic crust. It has a great diversity of topographic features like dry land. Huge mid-ocean ridges extend thousand miles; seamounts, guyots and submarine volcanos dot the seafloors; the abyssal plains constitute the flattest areas on the earth's surface; and greatest depths occur in long narrow deep-sea trenches located along the ocean margins, associated with island arcs, usually on the ocean side of the island arcs, such as the Mariana Trench in the West Pacific, that is the deepest trench having

a depth of 11,034 m (Fig. 9). From the bottom of the Mariana Trench to the summit of the Mount Everest the relief is even 20 thousand meters. The distinctive topographic units have quite different areas, shown in table on the following page.

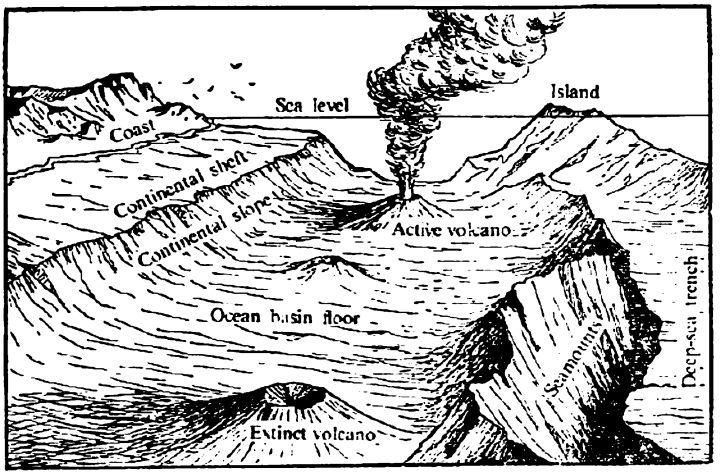


Fig. 9 Submarine topography

Are the distributions of the lands and the oceans constant all through the ages? Do the lands and the seafloors have the same undulate appearances as they were formed? How is the earth's surface sculptured into mountains and valleys? We are still seeking the answers.

Areas, depths, widths, slopes of the topographic units on seafloors

	Units	Depth (m)	Width (km)	Slope	Area (m. km²)	% of the oceanic total surface	% of the continental total surface
Continental margin	Continental shelf and slope	200 (max. 500)	4-1,000	0.10	>55.4	15.3	10.9
	Continental rise	1,400-3,200	20-90	4.3(20)		5.3	3.8
	Island arcs and deep sea trenches	2,000-6,000 (deepest 11,035)		0.01-0.0143	6.1	1.7	1.2
Ocean basin floor	Abyssal plain	4,000-5,000		<0.001	151.5	41.8	29.7
	Submarine volcanos and seamounts				5.7	1.6	1.1
	Abyssal hills				5.4	1.5	1.1
	Mid-ocean ridges				118.6	32.7	23.2

The everchanging crust

Over a thousand years ago the fact that "seas changed into fields" was mentioned in ancient Chinese classics. The land and the sea are not always unchanging, but in fact they are changing ceaselessly.

The Himalayas, the highest mountain range of the world, is not as high as it was created. The wide area where stands the Himalayas today was a turbulent sea pertaining to the ancient Mediterranean Sea 30 m.y. ago. The crust of the Himalayas had been lowered from two billion years to 30 million years ago, receiving 30-thousand-meter thick deposits during the long time span. In these sediments fossils of many animals and plants once inhabiting in ancient shallow seas have been found, such as trilobite, coral, alga, ichthyosaur, etc. The strata are the material evidence for the subsidence of the crust of the Himalayas. About 30 million years ago a strong crustal movement took place which caused the rapid rising of the Himalayas. All the strata under the sea were lifted out of water surface. In recent years, for example, fossils of *Hipparion*, an extinct three-toed horse, were found in strata in Tibet, which in most cases roomed and grazed in the warm, damp subtropic forest-grasslands at an altitude of 500 to 1,000 m about six million to ten million years ago. The fossil quarries, however, are now located at an altitude of 4,100 to 4,500 m, high up in the snowy Himalayas. This fact indicates a rising of three thousand meters of the Himalayas during this period. Today the Himalayas are still rising as yet (Fig. 10). However, we can not perceive the

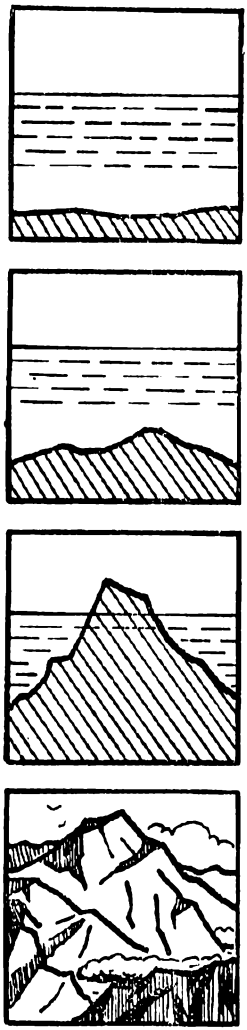


Fig. 10 Schematic sketch shows the Himalayas rising out of the sea

growth in such a short time with the naked eye.

Besides the fact that the seas give rise to mountains mentioned above, likewise there is also the change of land of the past into the sea today. An apparent evidence is the Taiwan Strait, at the bottom of which the ancient channels once connected to the mainland still remain.

The varied coastline of Naples bay in Italy is a typical example of the modern crustal movement. At the times of the ancient Rome, in 105 B.C., a temple named Jupiter Serapis was founded in Puzzuoli, a coastal city. Today only three 12 meters high white marble columns of the temple are preserved (Fig. 11). The parts of the columns from 3.6 to 6.3 m in height above the platform are covered with many holes drilled by marine rock-boring clams (Fig. 12). Some shells can be found in these holes. Based on the facts stated above and the historical record, conclusion can be drawn that after the erection of the temple these columns were once buried up to 3.6 meter by ashes from eruptions of volcanos.

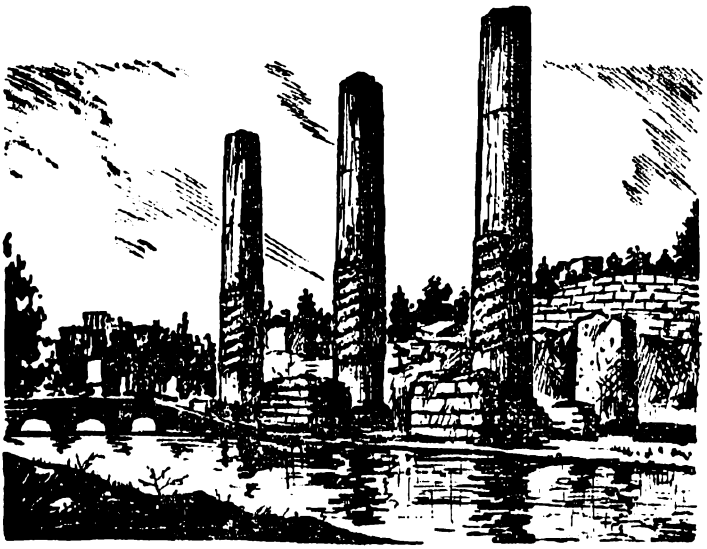


Fig. 11 Ruins of the temple at Naples

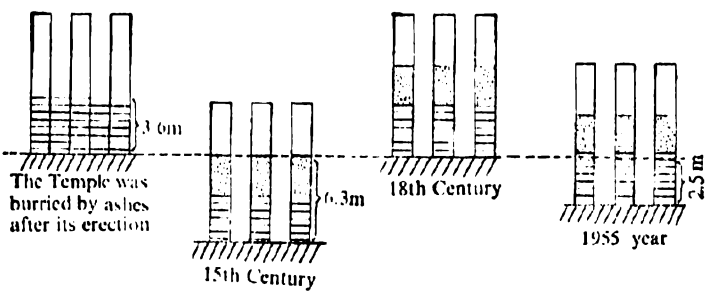


Fig. 12 Marks on the surface of the three columns indicating fluctuation of sea level. The parts covered with ashes (dashes); holes bored by marine organisms (dots)

The area then sinked gradually until more than six meters of the columns were inundated in sea by the 15th century. In the 18th century the sea level fell off, exposing the columns to the air. With the crustal subsidence the columns were again submerged 2.5 meters up to 1955. The subsidence rate maintains over two cm per year ever since. The example indicates that the coast nearby Naples has been in fluctuation.

The face of the earth has been changing ceaselessly. What we see today is only a scene in the long history of the crust's evolution, passing like a shot.

How does the earth's crust change itself?

When we observe in field the configuration of the strata that constitute mountains or hills, we find that few of them are horizontal; on the contrary, most of them are bended, tilted vertically or even overturning, that younger strata are overlaid by old ones, and that some strata completely break and rift into pieces. Why and how do these phenomena occur? The answer is that in the long geological time some of the strata originally horizontal or almost horizontal are bended, becoming folds; some rifted and faulted, becoming faults under the action of force over a very long period (Fig. 13). The crustal movement results in the deformation of the primary positions and structures of the strata. The deformation is called tectonic change.

In studying the tectonic changes of strata caused by crustal movement, it is considered that a huge amount of

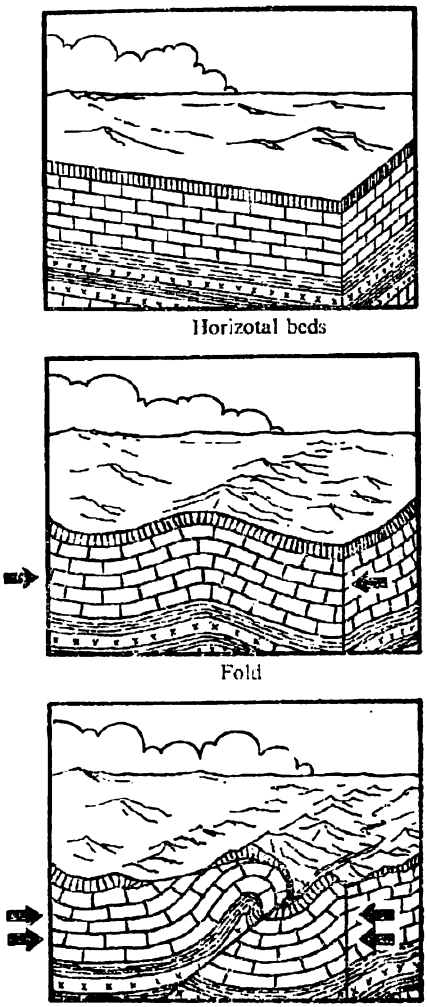


Fig. 13 Folds and faults

heat energy resulted from the decay of radioactive elements accumulates in the upper mantle. In the upper part of the upper mantle rocks are almost in a melted state because of the high temperature. The weak layer is the asthenosphere which yields plastic flows.

The physical character of the asthenosphere is not worldwide uniform. Convection of materials is formed in parts of the asthenosphere where the temperature is higher. The flow of hot materials rises from hotter mantle, then diverges sideways, and finally sinks beneath a trench. It acts on the lithosphere, causing the horizontal movement of the crust. Thus the strata are compressed, elongated or contorted and

its primary configuration and structures are thoroughly changed.

Li Siguang, a Chinese geologist, held that the earth's rotation and the change of rotation rate were the motive force of the horizontal movement of the crust. He studied the tectonic movement from the dynamic point of view, to trace the way of how the force acts on the crust and to analyze the dynamic nature of the crust and the distribution of stress in rocks. As a result of his study he recognised several major tectonic systems from the intricate tectonic phenomena. Based on the analysis of distributions of these systems and compounding of structures, together on model experiments and theoretical inference, he established the geomechanics to guide exploration of mineral resources and groundwater, prediction of earthquake and study on engineering geology, etc.

The force coming from the interior of the earth, which moves the crust, is called endogenic force. Under its action folds and faults come into being, and earthquakes and volcanos occur.

On the other hand, many factors such as sunlight, air, water, organisms, destroy exposed rocks, weathering them to debris, sand and soil (Fig. 14). Through wind and water current, erosion and transportation occur. The debris, sand and soil are carried to low ground and gradually fill them. The force from the exterior of the earth, intending to level the earth's surface, is called exogenic force.

While endogenic force gives broad relief to earth's surface, exogenic one intends to smooth it. These two forces

act on the earth's surface simultaneously, modifying its appearance and sculpturing various landscapes.

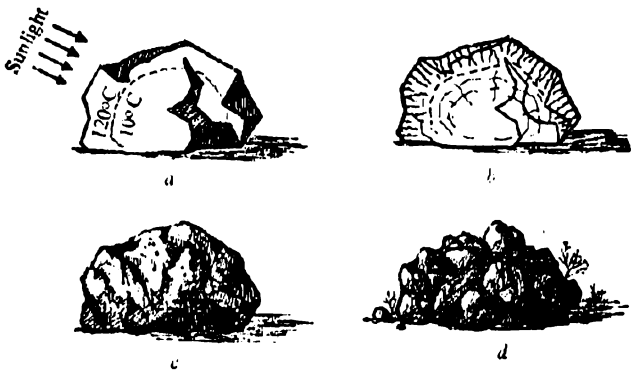


Fig. 14 Weathering of rocks

a- Temperature difference between inner and outer layer of rock, an important cause to destroy rock;
b- Destruction of rock caused by expansion and contraction under the alternate heating and cooling;
c- The rock disintegration process;
d- The making of soil

Plate tectonics

Continental drift — a fresh idea came out. When we look at a world map and glance over the distributions of the oceans and the continents we will see an interesting phenomenon that the shape of each continent is more or less triangular, with one of the apexes pointing southwards. The six continents fall into three groups, roughly symmetrical in a north-south direction, except Antarctica occupying a corner by itself. An even more interesting phenomenon is the remarkable

similarity in the coastline on each side of the Atlantic Ocean. The projecting part of South America toward the southern Atlantic, where Brazil lies, amazingly fits Gult of Guinea, the hollow coast of Africa. Is it a natural coincidence or what?

At the beginning of the century Wegener, a German meteorologist, noticed the above mentioned fact and other geological and paleontologic evidences and put forward the hypothesis of continental drift. According to this hypothesis, the widely separated continents of today were unified about 300 m. y. ago. The unified landmass named Pangaea, meaning "all land", was encompassed by the ancient superocean. South America, Africa, India and Australia were originally connected together to form a single landmass called Gondwanaland; to the north of it was Laurasialand consisting of Eurasia and North America. Between the two unified continents lay the ancient Mediterranean. The break-up of the supercontinent began about 200 m. y. since when cracks had occurred in the vast landmass. Then America drifted westwards, left the Atlantic behind it; Africa, India and Australia drifted northwards. Gradually the current location of the continents emerged (Figs. 15, 16).

In different geological models in Wegener's days, the stability ruled the academic circles before the theory of continental drift saw the light of day. The pursurers of the stability regarded the vicissitude of the land and the oceans as caused by the different degrees of rising and sinking vertically in different parts of the crust. They thought the seemingly changed locations of the ancient continents and oceans, related to the earth's axis and the equator,

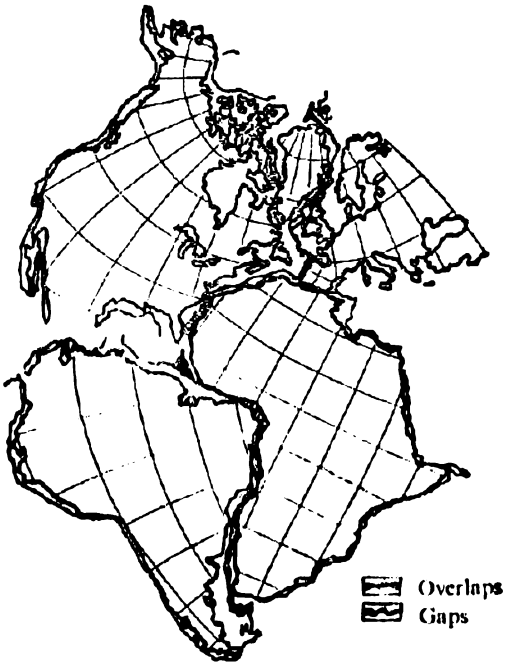


Fig. 15 The so-called 'Bullard fit' of the continents bordering the Atlantic

were the results of changes in positions of the earth's axis and the equator. However, continental drift based itself on the relative displacement of continents to oceans and also on those of both to the earth's axis and the equator. All these lateral displacements are the result that continents themselves move. So it is not surprising that a dead set was made at continental drift by those who saw the seas oscillating and the continents rising slightly. Continental drift itself, of course, at the same time, had fatal weakness in explaining its mechanism, and

a

b

Fig. 16 The separation of a supercontinent

also was devoid of some necessary arguments. Therefore it quieted down after created a sensation in the scientific world for a time.

In the middle of the 1950s with the rapid progress of paleomagnetics, it was discovered that the positions of paleomagnetic pole and the curves of polar wandering measured from different continents were not the same, but had a systematic error. If we adjusted the positions of the continents the curves and the paleomagnetic polar positions would

coincide by and large. Then the revival of interest in continental drift came after the hypothesis had been silenced for a considerable time and new progress were made.

The establishment of the seafloor spreading. Development of oceanic science enriches our knowledge about the ocean floors, and at the same time abundant data have been gathered. In 1961, American geologist, H. H. Hess expounded the hypothesis that he called seafloor spreading. Scientists discovered that on the floor of each ocean there was a mid-ocean ridge extending even ten thousand km. The hypothesis assumed that melting mantle material rose beneath the crust of a mid-ocean ridge, intruded and extruded along the ridge where it solidified from cooling, forming the new crust. New material went up continually to split the crust formed previously and pulled each half laterally aside from the crest; again new crust patched the gap (Figs. 17, 18). As the process

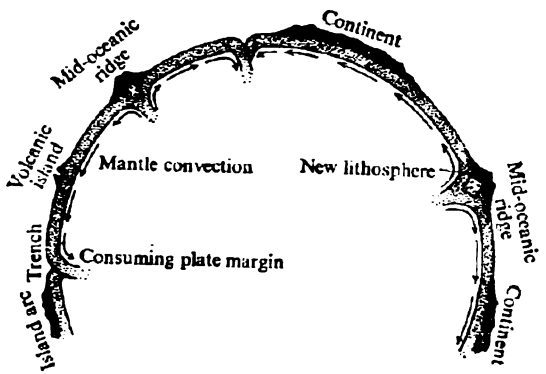


Fig. 17 Sketch map of mantle convection

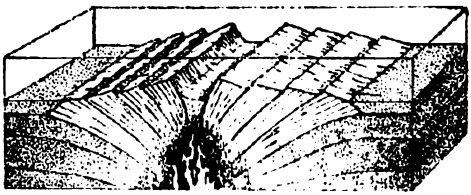


Fig. 18 Mantle materials rise with ascending currents

went on, seafloor spreaded constantly. Investigations show that the closer the rock is to the mid-ocean ridge, the younger it is, the farther the older. That is one of the evidences to support seafloor spreading. With the spreading of seafloor and the lateral movement of oceanic crust collisions take place when oceanic crust meets continental crust; the oceanic crust, for it is more dense, will dive into the mantle beneath the continental crust. Island arcs or coastal mountains rise as a result of the uplift of continental crust, whereas deep sea trenches are produced where the oceanic crust dives.

The spreading rates are not the same worldwide. It is 10 to 12 cm per year in the eastern Pacific; 2 to 3 cm per year in the Atlantic. These rates are considerable from the view point of geological time. It implies that, if they move at such a rate, oceanic crust will be replaced once every 200 to 300 m. y. Although the earth's age is perhaps more than five billion years and the oldest rock of continental crust has been found to be 4.6 billion years old or so, scientists have never found, in ocean floor, sediments more than 200 m. y. old, which is another evidence to support seafloor spreading.

The birth of plate tectonics. Plate tectonics, a global tectonics, is the corollary of seafloor spreading. It regards the lithosphere not to be a single massblock but to be made up of perhaps a dozen plates varying in size. Of them six major plates are Pacific plate, Eurasian plate, African plate, American plate, Antarctic plate and Indian plate (Fig. 19). The latter five contain both oceanic and continental crusts, whereas

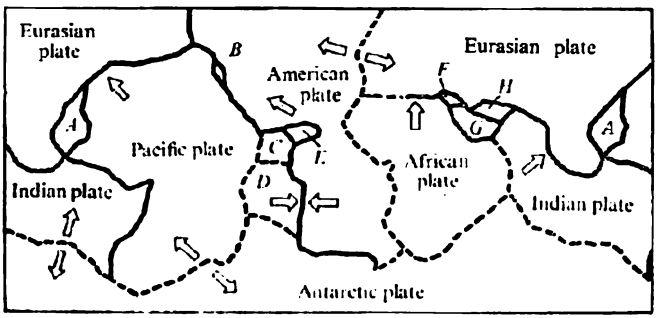


Fig. 19 Six major plates (named) and some minor plates (lettered)

——Zones where plates move apart
——Subduction zones
⟶Direction of plate movement

A - Philippine plate;
B - Juan Defuca plate;
C - Cocos plate;
D - Nasca plate;
E - Caribbean plate;
F - Turkish-Aegean plate;
G - Arabian plate;
H - Iran-plate

the Pacific plate has almost only oceanic crust. All the plates are moving ceaselessly. Generally the crust nearby the center of a plate is relatively stable, the boundary regions between any two plates are more active.

According to plate tectonics, both continent and ocean have their days of birth and death. The ancient Mediterranean, called Tethys, lying between Eurasian plate and Gondwana from the west-east. But the large Tethys Ocean is tottering on the brink of the grave today, to be and having partially been replaced by collision zone. Then where is the birth place of an ocean? Studies on plate tectonics show that the East African Rift Valley is an aborning ocean; Red Sea and the Gulf of Aden, being spreaded, are in their childhood as an ocean in the making; adult as the Atlantic is, it still keeps spreading; the Pacific, too old to resist the compression invited by Eurasian continent and American continent, is losing its dimension; and the small Mediterranean Sea, on its last legs, is reducing and rising as dry land. The trace of the ocean of the past is the suture line such as the Himalayas and the northern areas to it.

Continental drift, seafloor spreading and plate tectonics seem to be the three parts of a wonderful trilogy about the history of the earth's crust — initially it was known as continental drift, then as seafloor spreading and finally as plate tectonics, which tells us that in the upper part of the earth exist not only vertical movement but also, on a larger scale, horizontal movement even covering a distance of kilometers; which also tells us that active "metabolish" is afoot and that the earth's crust is being renewed, here it disappears there it emerges.

Ocean occurs and grows up where it did not exist, or on the contrary, ocean decreases and disappears where it was surging up. The earth is none of a globe dull and tedious, but animated and filled with vigor.

CHAPTER III

CATASTROPHE OF THE EARTH —VOLCANOS AND EARTHQUAKES

Under the action of endogenic force, the earth's crust folds, faults and at the same time moves vertically and horizontally, making the earth's surface rugged and rough. This process usually goes slowly. But sometimes violent events may take place, those are volcanos and earthquakes.

Volcanic activity

Volcanic eruption is a spectacular natural phenomenon. It was recorded in ancient Chinese classics long ago. In 1719 and 1720 (in the Period of Kang Hsi, Qing Dynasty) for example, the volcanos of Wuda-Lian-Chi in Northeast China erupted one after another. Description of one of the eruptions says, "Fires flamed from the ground one day, stones flew; sounds echoed in the fields. The scene lasted several days, then fires died away . . ."; "Suddenly flames and smokes jetted, touching the sky; sounds like thunders, crashed in

snatches for a night, being heard over 50 to 60 li away. . . . Heat could be felt even 30 li away."

That is all that is. Before a volcano is to erupt, sounds thunder under the ground and the earth shakes. Then hot gases, ashes and stones are launched high into the air from crater, hatching the volcano with a great volume of fiery clouds ranging even kilometers; red-hot lava pours out from the crater and spills downhill. Mixed with gases and water vapor, ashes fall on the ground, forming hot debris flow which is powerful enough to destroy and bury buildings on the ground. In 79 A.D. the explosion of Vesuvius volcano of Italy ruined and buried, with debris flow six to twenty meters thick, two busy cities — Pompeii and Herculaneum (Figs. 20, 21). The site of

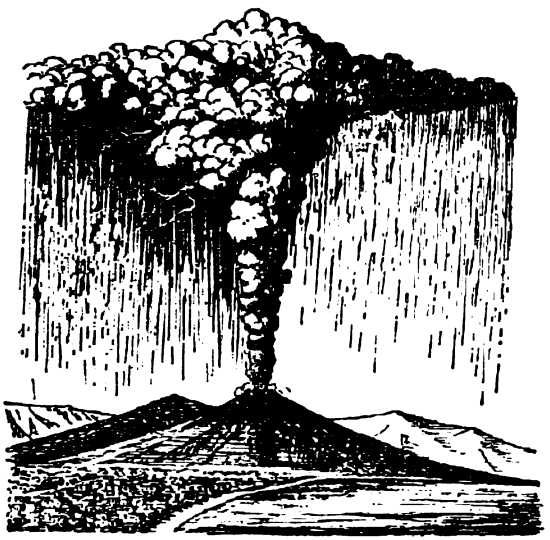


Fig. 20 Vesuvius in eruption (1882)

Fig. 21 Ruins of Pompeii

Pompeii has been partially uncovered now and serves as a tourist's highlight. The Vesuvius has never rested since then. It erupted again in March of 1944.

It is difficult to observe the entire process of volcanic eruption simply because of its suddenness and violence. The formation of Paricutin volcano in Mexico provides a good opportunity for us to learn the inside story of a volcano. As a "living specimen" for study on volcano, the Paricutin volcano has a wonderful story about its birth.

Fifteen days before the appearance of the volcano the ground shaked violently, and rumbles under the ground could be heard. One day in February of 1943 a farmer working in his cornfield suddenly felt the ground rocking with rumbles.

He saw a puff of smoke coming out of a hole, then a fissure appearing, from which black smoke spurted and at the moment sulphurous smell irritated his nostrils. Trees around the fissure caught fire and springs nearby dried. The hole spurting smoke enlarged to two meters in diameter and lava was boiling in it. Next morning a ten-meter-high cone was deposited around the hole in the cornfield. The cone grew up to 100 m high a week later. Lava pouring from the hole, like a flow of melted iron, devoured the village and set fire everywhere. The cone was 336 meters high above the cornfield one year after. Even rock pieces of weighing ten to twenty tons were thrown out of the crater; gases and ashes gushed into the air up to 500 m high, scattered some hundred km away. Personally man saw a volcano "growing up" quite unexpectedly from the cornfield (Fig. 22).

The story tells vividly that volcanic eruption is the natural result of the gush of magma from the interior of the earth. With higher temperature and pressure in asthenosphere magma is mobile and eager to find a way out. Through the weak points of the crust where there are many cracks magma goes upwards. The magma, with high pressure produced by expansion of the gas and vapor compressed in it, pierces through the overlying beds, where a volcano is thus formed. Lava flows in every direction and becomes hardened rocks through cooling. A volcano will grows larger and larger if eruptions take place time and again. We call hardened piece of lava thrown out of the volcano a "volcanic bomb" (Fig. 23) and the cup-shaped cavity a crater where come out all the volcanic material. Some craters may be filled with water,

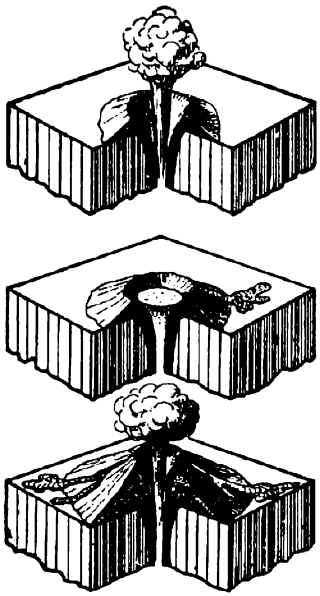


Fig. 22 Cone in the making

Fig. 23 Volcanic bomb

forming crater lakes. At the top of Mount Baitoushan of Changbaishan mountains there is a crater lake 13.11 km in circumference and 373 m in depth. It is 2,200 m above the sea level, so is called "Heavenly Lake" (Fig. 24).

Fig. 24 Crater lake at the top of Baitoushan

Most of the volcanos in the world became infuriate when they are in eruption. Some are relatively quiet, with a small amount of material being thrown out and lava flowing smoothly, like those on the Hawaiian Islands, for example.

Volcanos can be classified according to their activities into three types: active, dormant and extinct volcanos. A volcano is active if it presents volcanic behaviors at present or is in its active circle though it seems to be tranquil now, such as Kilauea Volcano, Hawaii. A dormant volcano means that it is recorded to have been active in the recorded history of man, but has been silent for a long time since. Those that erupted long before the recorded history but have been dead since then are extinct volcanos. This division is far from exact. For example, although in dormancy for 123 years, Mount Saint Helens in Washington State, Northwest U.S., erupted abruptly on March 27, 1980, and soon after erupted again on May 18, 25 and June 12. It became violently active after long quiescence. About one billion m^3 ashes and lava were thrown out in the eruption on May 18, followed by a terrible landslide

that cut the volcano by 173 m and lowered the elevation from 2,903 to 2,730 m. The shock waves penetrated clouds and reached to a height of several kilometers. Air current brought ashes to places over 4,000 km away. Ash layers of 1.3 cm thick were deposited at the distant areas 800 km from the volcano. Calculation made by American geologists shows that the energy released from the eruption is 2,500 times that of the atomic bomb dropped at Hiroshima by American Air Force in World War II.

There are in all 699 active volcanos in the world today. In China most of the volcanos (a total 600 at present) are extinct ones. There are many of extinct volcanos, for example, around Datong, Shanxi Province, that were active during Quaternary Period, about one million years ago. Many cones, volcanic bombs and floatstones are seen in the surrounding area. Volcanic activity in the area weakened in Holocene except at Dongping, in the vicinity of Datong. Volcanic activity has no longer been documented in the historical record. A number of Han Dynastic graves recovered nearby some cones warrants the extinction of volcanos. However, the Wuda-Lian-Chi volcanos were still active in Kang Hsi Period in Qing Dynasty. They may be taken as dormant.

Volcanic activity often causes damage to man. The foregoing eruption of Mount Saint Helens had caused a great forest fire which devoured all the trees in an area of 390 km^2. More than 60 thousand acres of apple trees in Washington State were covered with ashes. Innumerable apples dropped, which incurred a loss of thirty million dollars to the fruit industry of the state. Snow covering mountain tops was

melted to form surging debris flow which shattered bridges nearby the volcano. Black clouds darkened the sky over Washington and its neighbor state, Idaho, overshadowing the cities and countryside. People had to drive their cars with the headlights on. Highways were carpeted with ashes five to seven cm thick. The total loss caused by the eruption was estimated at more than 1.6 billion dollars. President Carter said, when he inspected the site, that this eruption was one of the most disastrous in the history of the United States.

Volcanic activity, on the other hand, provides man with abundant resources. Usually, geothermal sources, which can be made use of by us, concentrate where volcanos do. And thanks to volcanic activity, some minerals such as sulphur, arsenic, boron and radioactive elements, are dissolved in hot spring so that the spring water has special curative effect to certain diseases. Sulphur in the crater can be exploited. Japan and Mexico, both having many volcanos, are noted for their richest sulphur resources in the world. Blocks of lava are fine building material and ashes rich in mineral content are fertile soil. Indonesia has the greatest number of volcanos in the world. The Indonesian people harvest on the fertile soil of volcanic ash origin.

Earthquakes

Earthquake is a natural phenomenon, too. Violent earthquakes often cause great damage. About five million earthquakes occur in the world every year, among them 50 thou-

sand or so could be perceived and on an average only 18 are strong earthquakes causing serious damage are virtually occur in oceans and mountain districts where few people live, strong earthquakes causing serious damage are virtually three to five on an average every year in the world.

According to different causes we distinguish earthquakes into three types: tectonic, volcanic and depressive earthquakes.

The extrusion of magma, when volcanos are in eruption, sets motion to the crust and causes the volcanic earthquake.

When limestone strata underground are dissolved by groundwater, caverns will be formed. The roofs of the caverns may cave if they cannot bear the weight of the overlying rocks. Collapse may occur in those old mines where empty tunnels are left after minerals have been digged out. In these cases depressive earthquakes occur due to abrupt collapse.

These two types of earthquakes occur infrequently, less than 10% of the total, and have a limited range of effect.

Crustal movement causes tectonic earthquake. Tectonic earthquakes occur more frequently, have wide effect limits and bring great disaster upon man. Xingtai earthquake in Hebei Province, 1966; Haicheng earthquake in Liaoning Province, 1975; and Tangshan earthquake in Hebei Province, 1976, are all tectonic earthquakes occurred in China. Therefore, we should focus our attention on tectonic earthquake and take it as the major danger to be prevented.

Tremendous energy stored in the interior of the earth produces strong stresses which are exerted on the crust to force it into changing. If the stresses accumulate in weak part

of the crust where rocks cannot stand them, abrupt rupture or faults will occur to release the energy stored. The rupture or faults of strata cause parts of the earth to shake. The waves propagate through the earth. As the waves pass through any one place, they produce an earthquake (Fig. 25).

Fig. 25 A 8—9 M earthquake in Fuyun, Xinjiang Province, 1931, caused mountains to fault

The point in the interior of the earth where an earthquake takes place is called focus and the point on the surface vertically opposite to focus is epicenter (Fig. 26). The distance between focus and epicenter is focal depth. Vibration at epicenter is strongest, farther away from the epicenter, vibration weakens. The distance from epicenter to the place affected on the surface is epicentral distance. Degrees of destruction are usually unequal even at points having an equal epicentral

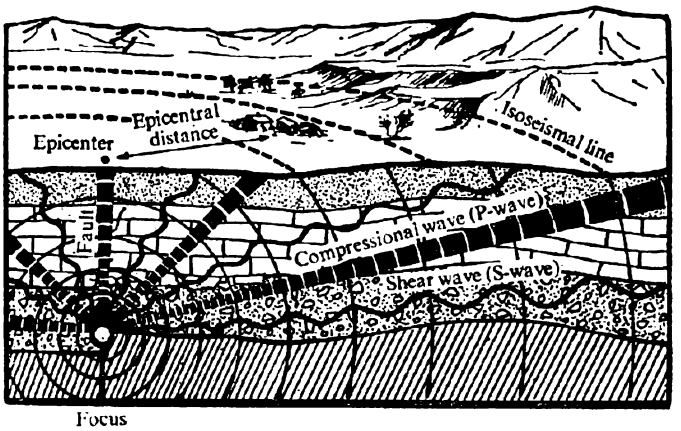


Fig. 26 Focus, epicenter and isoseismal lines

distance. Lines drawn through points of equal intensity plotted on a map are isoseismal lines. Most earthquakes have focal depths less than 70 km, whereas those causing greater damage often occur at a depth of 10 to 20 km. The greatest focal depth known by far is 720 km.

We use earthquake magnitude (M) to measure how strong an earthquake is. The greatest magnitude yet measured is that of the Chilean earthquake of May 22, 1960, about 8.9M. Normally a 2M earthquake is microseism that is barely perceptible. Earthquake 3—5 M can be felt by persons, so called "felt earthquake". Those over 5M are destructive earthquakes that really cause damage.

A measurement of local ground shaking and the degree of destruction to buildings are indicated by intensity scale that includes 12 grades.

Briefly, scale below 3 is not perceptible; scale 4—5 can be

felt by persons; when scale is over 6 buildings are damaged to different extent.

Magnitude and intensity have quite different meanings. Each earthquake has only one magnitude but different intensities in the circle that waves can reach. Intensity varies depending on different epicentral distances, geological structures and spreading situation of the waves. Tangshan earthquake, for example, had a magnitude of 7.8 and an intensity over 10 in the epicentral area, but in Tianjin intensity was about 7, in Beijing about 5. The situation is like an explosion of a bomb: the closer to the bomb, the higher the degree of destruction is. If the quantity of the dynamite in the bomb is expressed by magnitude, then intensity is the degree of destruction resulted from the explosion of the bomb to things at different distances from the bomb.

Because of the diversity of geological structures, rocks and soil qualities and because of the different resistances of buildings to vibration, intensity may vary in a wide range even if measured at a same distance from the epicenter, i.e., intensity is distributed irregularly. For instance, in the case of 1976 Tangshan earthquake, intensity measured around an area in the vicinity of Yutian county is lower than that of the nearby area. Intensity at Caiyu district, Daxing county, Beijing, is higher than in its neighborhood.

Intensity closely relates to focal depth. If focus is near the surface, intensity will be greater though magnitude is low and devastating range is limited. In the dead night of February 29, 1960, an earthquake attacked the sightseeing city of Agadir, Morocco, close to the Atlantic. Although it was only 5.8M,

the earthquake shattered most, if not all, of the buildings of the city within fifteen seconds. The focal depth being merely three to five km answered the why. Suppose focal depth is 10 to 30 km, magnitude, focal intensity, degree of destruction, energy released, etc., have their relations shown in table below.

Epicentral intensity	Magnitude	Qualitative description	Energy released	Influence and destruction at epicenter	earthquake number (per year)
I	1.9	Negligible	Equal 1b. TNT	Measured by instrument	700,000 (below 2M)
II	2.5	Weak		Felt by persons sensitive; objects swing slightly	300,000 (2-2.9M)
III	3.1	Slight	Equal 600 KWH electricity	Felt by persons at rest. Vibrations resemble those from a passing truck; parked cars may vibrate.	49,000 (3-3.9M)
IV	3.7	Medium		Felt indoors like the vibration from a passing heavy truck; a few sleepers awaken; windows, plates sound; parked cars vibrate; felt by a few walkers.	

Epicentral intensity	Magnitude	Qualitative description	Energy released	Influence and destruction at epicenter	earthquake number (per year)
V	4.3	Less strong		Felt by most people; many sleepers awaken; doors, windows and house frame sound. Plates, glassware break. Pendulum clock stops. Bubbles appear in pond and domestic animals are disturbed.	6,200 (4-4.9M)
VI	4.9	Strong	Equal an atomic bomb of 20,000 t. TNT	Felt by all; many in fright. Chimneys fall. Furniture moves or overturns. Water vibrates strongly. Trees shake. Domestic animals run out.	
VII	5.5	Very strong		Most run outdoors in fright. Poor masonry cracks; noticed by automobile drivers. Small fissures occur on surface. Groundwater table changes.	800 (5-5.9M)

Epicentral intensity	Magnitude	Qualitative description	Energy released	Influence and destruction at epicenter	earthquake number (per year)
VIII	6.1	Destructive	Equal a H-bomb of 1mt. TNT	General panic; all run outdoors and have difficulty to keep balance; damage to good unbraced masonry; some damage to good, somewhat reinforced masonry. Monuments fall. Heavy furniture overturn. Some underground pipes break. Mud and sand rise from fissures.	120 (6-6.9M)
IX	6.7	Devastating		Causes serious panic; good unbraced masonry heavily damaged; reinforced masonry seriously damaged; general damage to foundations. Underground pipes break. Ground rifts, fissures about 10 cm across.	

Epicentral intensity	Magnitude	Qualitative description	Energy released	Influence and destruction at epicenter	earthquake number (per year)
X	7.3	Disastrous		Causes serious panic. Few well-built structures survive; foudations crumble; rails bend. Ground rifts seriously; fissures a few km long. Landslides, barrier lakes formed.	18 (7-7.9M)
XI	7.9	Seriously disastrous		Very few well-built masonry stand; wide fissures, large landslides formed. Underground pipes completely damaged; great loss of life.	
XII	8.5	Catastrophe	Equal 60,000 H-bomb of mt. TNT	Distorts lines of sight and level; damage nearly total; object thrown into the air; superficial and groundwater changed greatly.	one within a few years (8-8.9M)

Each earthquake undergoes its brew, development and failure. Usually there are a series of foreshocks occurring prior to the major one that takes place when foreshocks are getting stronger and stronger. And followed the major earthquake occur a set of aftershocks. In 1980 after the earthquake of July 28, 1976, aftershocks over 5M still took place in Tangshan.

Strong earthquakes cause great loss of life and property and strike national economic construction. If we can predict when, where an earthquake will happen and how strong it will be, relevant preventive measures could be taken in due time to reduce the loss to the minimum.

As early as in 1966, soon after Xingtai earthquake, the late premier Zhou En-lai pointed out that earthquake prediction was possible based on the signal that omens an earthquake; although earthquake is an abrupt event in nature, there must be a quantitative change prior to a qualitative one before a strong earthquake eventually happen. A series of physical, chemical, biological and meteorologic changes might be observed when an earthquake is expected where stresses are accumulating. The changes before an earthquake are regarded as seismic signals. Timely observation and study of seismic signal and efforts to search for how an earthquake occurs, i.e. the conditions, process and the law of its change, together will make it possible to predict when, where an earthquake will happen and how strong it will be.

Earthquake prediction should be a task in which the masses can take part, by using various methods such as observation of minor shocks, surveying abnormal changes of topography, groundwater table, telluric current, telluric mag-

netic force, temperature, stresses and gravity as well as abnormal behaviors of animals. An analysis must be made from the data gained from the observations and surveying so that we can make out in all its aspects the "law" that governs earthquake and well forecast and predict earthquake.

The distribution of earthquakes and volcanos

The geographic distributions of earthquakes and volcanos are regular. Both of them take place in the areas where modern crustal movements are active. Therefore earthquake and volcano are almost coincident in distribution.

There are two major zones that are dotted by most of the earthquakes and volcanos in the world: one is the circum-Pacific seismic belt including Japan, Taiwan, the Philippines, Indonesia, New Zealand and the coastal areas of South and North America; the other is the Himalayas-Mediterranean belt (the Alpide belt), which links Burma, Hengduanshan mountains, Himalayas, the Pamirs, the middle Asia, Mediterranean and its neighbor areas (Fig. 27). From the point of view of plate tectonics, these two belts are situated in collision boundaries of plates, where are the most active areas of the modern crustal movements and concentrate most earthquakes and volcanos (about 95% of the total earthquakes in the world).

China is situated between the two belts, so has many earthquakes. Earthquakes recorded in Chinese history are mainly distributed in the following five major regions: 1) Taiwan province; 2) Fenwei faulted zone, Taihang Mountains, Beijing-Tianjin-Tangshan, Zhangjiakou, all along the coastal area of Bohai; 3) the Hexi Corridor, Liupanshan Mountains and Tianshan Mountains in Northwest China; 4) west Sichuan,

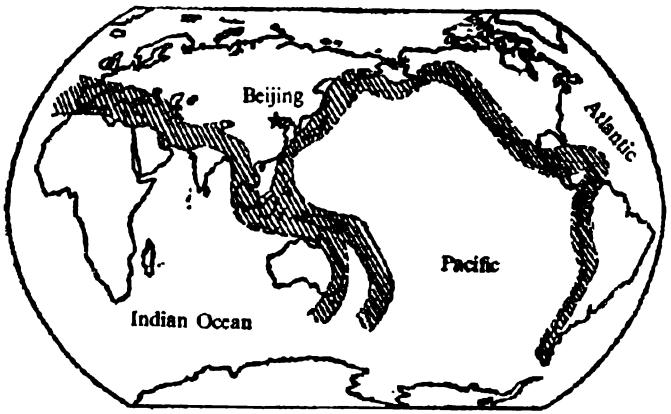


Fig. 27 Distributions of earthquakes in the world

middle and eastern parts of Yunnan and Tibet along Southwest Qingzang Plateaus; 5) the coastal areas of Guangdong, Fujian (Fig. 28).

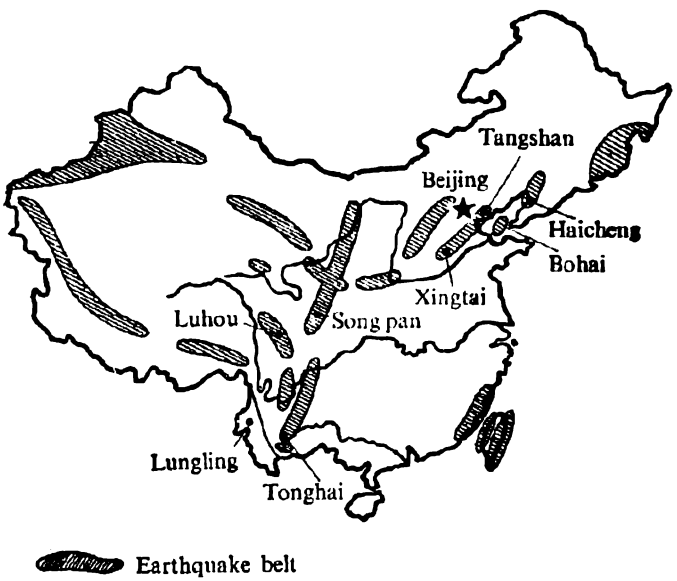


Fig. 28 Map showing distributions of earthquakes in China

CHAPTER IV

ROCKS—THE CONSTITUENTS OF THE CRUST

Not only towering mountains but also odd and rare stones are rocks, the fundamental building materials of the crust. They are bound up with our everyday lives and productive activities. However, what on earth are rocks composed of?

Elements, minerals and rocks

Chemical elements are the essential composition of rocks. Those which are of considerable importance to make up of the crust among the more than a hundred chemical elements now known in nature are Oxygen, Silicon, Aluminium, Iron, Calcium, Sodium (Natrium), Potassium (Kalium), Magnesium, Titanium and Hydrogen. They are about 99.35 percent of the total weight of the crust.

Abundance of essential elements in the crust (%)

O	46.0	Mg	2.8
Si	29.0	Na	2.3
Al	8.3	K	1.7
Fe	5.8	Ti	0.64
Ca	5.2	H	0.14

American geologist Clark first determined the percentages of 50 elements in the crust. So the percentage of each element in the crust is expressed as Clark Value afterwards. Nevertheless, elements in the crust are not evenly distributed because they enrich in a different way depending on their chemical properties. Titanium, for example, has a considerable Clark Value, but its rich ore is scarcely formed in the crust. On the contrary, copper, though has a Clark Value of only 0.0063, is easy to form rich ore deposit. Gallium has Clark Value of 0.0018 and Chromium has 0.0012. However, the former never forms ore, but the latter has many large-scale ore deposits.

Minerals are defined as naturally occurring substances, generally solid and inorganic, whose atoms and ions are arranged in regular, three-dimensional patterns that give each mineral a characteristic set of physical properties and chemical composition. Salt, a spoonful of it being indispensable to our bodies every day, is a mineral that is colorless or white

solid consisting of two elements: Cl and Na (Fig. 29). Gypsum, which is used in making beancurd food, is transparent or white, fibrous or tabular masses, consisting of Ca, S, H and O (Fig. 30). Graphite, which is metallically lustrous, grayish

Fig. 29 Rock salt

Fig. 30 Gypsum

black scaly masses and consists of only C, is greasy feel and marks paper, so used as the "lead" in a lead pencil.

Thus it can be seen that minerals are composed of either several elements or a single one. It is because of their different chemical compositions that minerals present a great diversity of forms, structures and physical and chemical properties, and it is based on its form, color, transparency, hardness, luster, etc., that we identify a mineral.

Although about 3,300 different kinds of minerals have been known to be present in nature as yet and the number is added at a rate of 50 per year, common ones account for only a few hunderd.

A mineral rarely exists alone as native element in the crust. Usually two or three are combined in regular pattern and definite proportion to form different rocks. If you have a piece of granite in hand, you may get an impression at the

first glance that it is nothing but a piece of white, light gray or flesh stone; on more careful examination you will see that it is constructed predominantly by three minerals: feldspar, quartz and mica. Sandstone used to sharpen your knife is a assemblage of, chiefly, quartz and feldspar. From observations of different kinds of rocks we come to the conclusion that rocks are assemblages of either one or several minerals combined in certain patterns under different geological conditions.

The most common mineral constituents of rocks are feldspar, quartz, mica, calcite, hornblende, augite, etc., which are known as rock forming minerals. Most of them are silicates, next to most are oxides and carbonates. Despite dwelling in different rocks, each mineral exhibits a set of distinct properties. For example, quartz in both granite and sandstone assumes white or colorless grains and vitreous luster all the same. Therefore identification of minerals is a basic step in recognizing different kinds of rocks.

According to their origin of formation we group various rocks into igneous, sedimentary and metamorphic rocks.

Igneous rocks

Igneous rocks are the major kind of rocks in the crust, about 65 percent of the total by weight.

They result from freezing of molten rock which intrudes into or is extruded out of the crust, so igneous rocks are subdivided into extrusive and intrusive rocks.

Temperature in the crust increases at the rate of 1°C for 33 m depth going downwards, and it is not stable until the

depth is great enough. It is now estimated that temperature is about 400 to 1,000°C near the "Moho". At the boundary between lithosphere and asthenosphere (at a depth of 60 km) the temperature ranges from 500 to 1,100°C, whereas in the asthenosphere it may be as high as 2,000°C. Although the temperatures are so high as to melt any rock no matter how hard it is, rocks do not melt entirely in fact but become thick magma under the tremendous pressure of 500,000 atmosphere of the upper crust. Containing a complex chemical composition and a great quantity of inconstant gases, the magma, under high temperature and pressure, becomes quite mobile and chemically active. The magma intrudes upwards through cracks into surrounding rocks, where, along with a sharp fall in temperature and pressure, it gradually differentiates and crystalizes to form minerals and the "frozen" magma becomes a body of intrusive rocks, such as olivinfels, diorite, granite, etc. After intruding into the crust, magma becomes intrusive mass of various structural shapes called batholith, laccolith, dyke and sill according to their shapes (Fig. 31). When a volcano belches, lava will pour out of it and solidify into extrusive rocks such as basalt, andesite, liparite, etc.

Most of igneous rocks are crystalline. Intrusive rocks are usually coarse-grained rocks, formed as the result of slow cooling, whereas extrusive rocks or volcanic rocks are those that are either very fine-grained or glassy, for they must be formed by rapid cooling on or near the earth's surface (because rapid cooling does not allow time for large crystals to grow). In addition, fumaroles are left in extrusive rocks

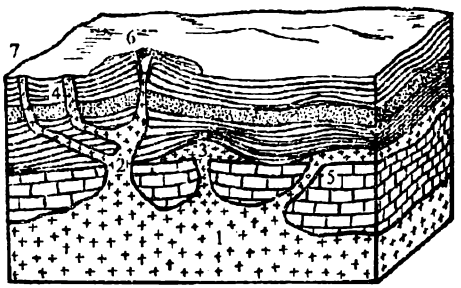


Fig. 31 Intrusive masses

1-Batholith; 2-Stock; 3-Laccolith; 4-Dyke; 5-Sill; 6-Cones; 7-Sill

when inconstant gases are released, and linear flow structures mark them as a record of lava flowing.

Of all igneous rocks granite is dominant in quantity and in distribution. It is also called "Mashi", meaning "spotted stone", as a popular name in Chinese because of its coarse surface and its grains visible to the eye. The three major mineral constituents in granite are quartz, feldspar and mica. Quartz is colorless or "white", usually transparent with vitreous luster; feldspar is flesh, white or gray and usually has a crystal structure of rectangle; and mica is black or white thin elastic flakes. What is more, granite contains some other kind of minerals, say, hornblende and augite. When these minerals present in different percentages granite assumes various colors: lightgray, pink, lightyellow, white, and so on. Granite is so hard that it stands a pressure of 2,000 kg per cm^2, thus to be good building material widely used in construction of bridge, dam, and in paving road and coating wall.

It supports the bridge on the Yangtze River in Nanjing and used to pave Tian An Men Square in Beijing. Mount Taishan in Shandong Province, Fangshan county in Beijing and Qinling Mountains in Shaanxi Province, are famous producing areas of granite in China. The body of the Monument to the People's Heroes at Tian An Men Square is the flesh color granite from Mount Laoshan near Qingdao city, and its foundation is the gray granodiorite from Zhou-Kou-Dian, Beijing (Fig. 32).

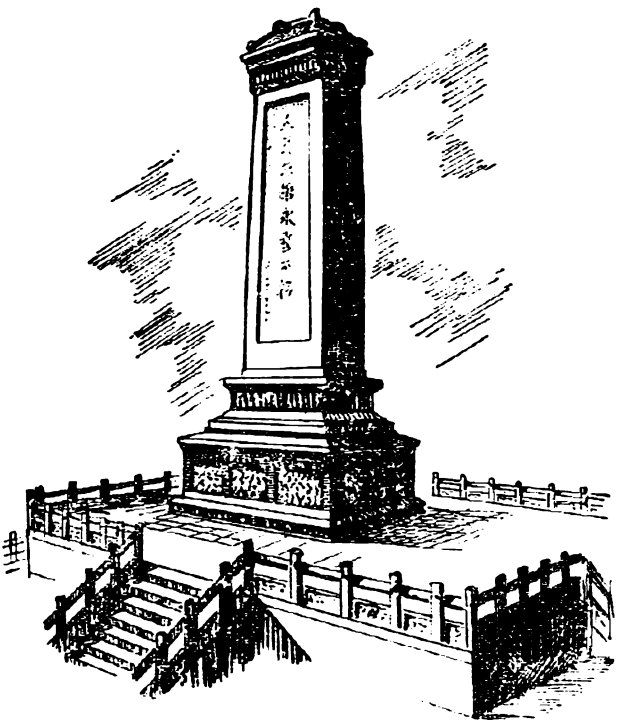


Fig. 32 The Monument to the People's Heroes

Sedimentary rocks

Although they are only 8% of the total weight of the crust, sedimentary rocks cover almost 75% of the continental surface, and widely distribute on seafloors as well.

Sedimentary rocks are formed through the action of exogenic force. Rocks exposed on the surface are destroyed into debris, sand and soil or broken into other substances in the course of weathering in which sun rays, ice freezing, wind, rains and even plant roots play important roles (Fig. 33). Then

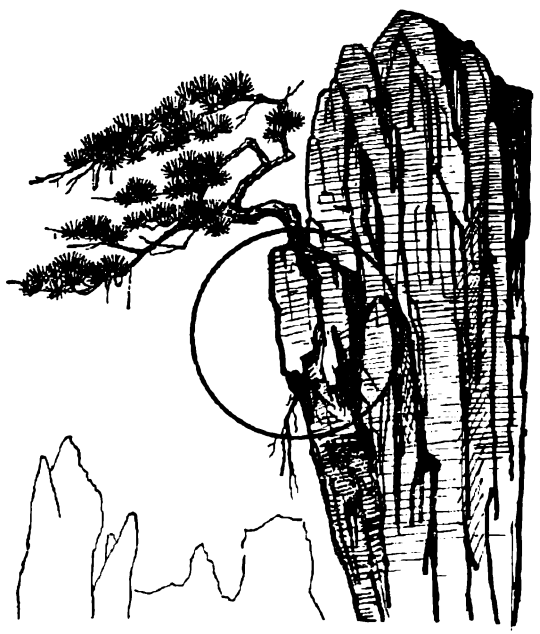


Fig. 33 Destruction of rocks from plant roots

water current, wind, glacier, and the like, deliver them to low-lying land or anywhere suitable for their deposition (such as rivers, lakes, sea, basins, etc.). Year in year out sediments accumulate to a great thickness. With increasing pressure and temperature the pores in sediments are compressed and water is squeezed out and at the same time silica, carbonates or iron oxides in solution fill the pores and cement the loose grainy sediments to form sedimentary rocks. The process includes, successively, four stages in general: weathering, transportation, deposition, and diagenesis and it spans a quite long period (Fig. 34). All sedimentary rocks used to be incorrectly

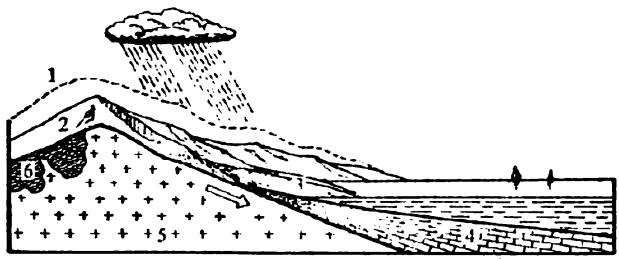


Fig. 34 The diagenetic process of sedimentary rock

1-Primary topography; 2-Weathering; 3-Transportation; 4-Deposition and the formation of sedimentary rock; 5-Igneous rock; 6-Metamorphic rock

regarded as hydrogenic rocks. Although most sedimentary rocks are through the agent of water, nevertheless, some of them may be also aeolian, glacial or volcanogenic. For instance, loess extensively spread over North China and its contiguous areas is mostly of aeolian origin.

Sedimentary rocks have a great number of family members. The more common ones are mudstone, shale, sandstone, breccia or conglomerate rock, limestone, dolomite, etc. The most notable property of sedimentary rocks is the bedded structure known as bedding or stratification (Fig. 35). We can observe on bedding surface ripple marks of water current or waves, footprints, trails, burrows left by ancient animals. Bed-

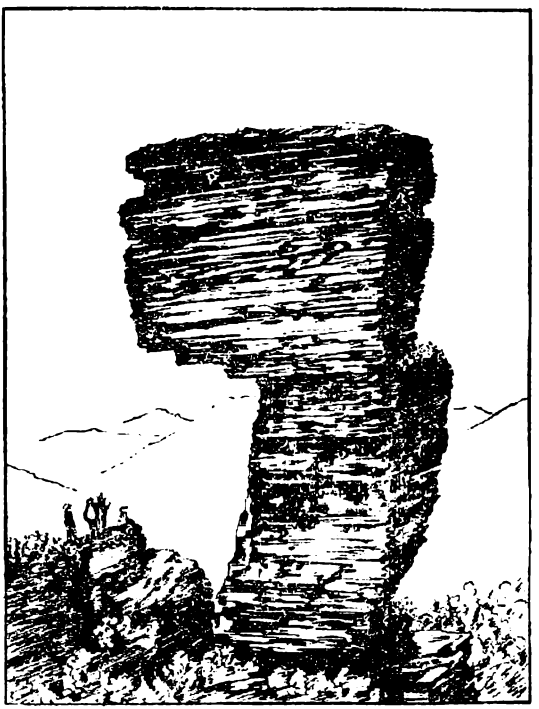


Fig. 35 Mushroom rock, composed of bedded slate, in Fanjingshan mountains, Guizhou province

ding surface also displays mudcracks resulting from drought, raindrop craters and salt pseudocrystal.

Rocks deposited in seas or large lakes usually have horizontal layers, whereas those formed in small lakes or accumulated at mountain foot are slightly inclined which vary in inclination corresponding to the basin. The initial horizontal beds become tilted, vertical or even overturning under the action of crustal movement. In measuring the orientation of a certain bed, geologists refer to its strike and dip. Strike is the direction of a horizontal line in the plane of a particular bed; dip is the angle between this plane and the horizontal when measured at 90 degrees to the strike. The direction of dip is that followed by a ball rolling down the plane. Strike, dip and the direction of dip, all the three describing the dimensional orientation of a bed at a certain place, are called attitude (Fig. 36).

Limestone is one of the wide-distributed sedimentary rock, mostly formed in ancient seas. The major mineral constituent of limestone is white calcite. Limestone is commonly gray-white or gray-black because of containing impurities.

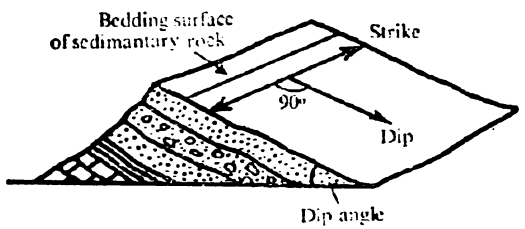


Fig. 36 Strike, dip and direction of dip

From its color it has the popular name "blue stone". The chemical composition of limestone is chiefly carbonate which will effervesces briskly when it meets even dilute hydrochloric acid. Limestone is widely used as building material for paving roads and building houses. There are columns encircling with carved dragons, standing at the Confucian Temple in Qufu, Shandong Province. These columns are made of Cambrain oolitic limestone quarried from mountains of the western Shandong Province (Fig. 37). Important use of lime-

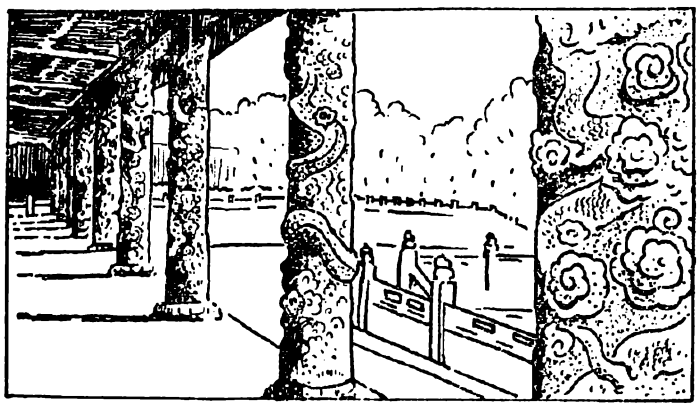


Fig. 37 Limestone columns at Confucian Temple

stone is to manufacture lime and cement, and it is also used in synthetic fibre industry as well as in smelting steel as flux.

Strata of sedimentary rocks are deformed by crustal movement mainly through two processes: folding and faulting. Faults and the axial parts of folds are favorable for ore magma to penetrating into surrounding rocks and to hausing

them to form ore deposits. Great number of cracks caused by faulting and folding in rocks are passages and storage of groundwater. By studying fold (Fig. 38) and fault (Fig. 39) we can

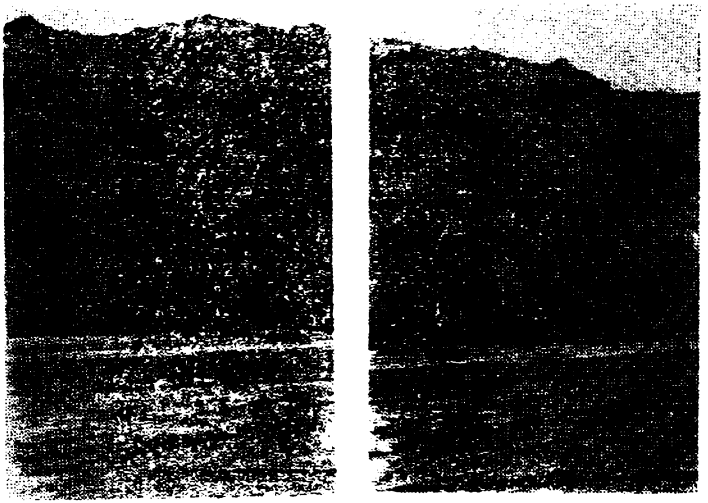


Fig. 38 Box fold in Kashi, Xinjiang province

Fig. 39 Fault found in Tibet

find out the direction of stress acting on strata and how strong it is so that we can further understand the crustal movement, say, its scale and other aspects. This aspect of study comes under the discipline of structural geology.

Metamorphic rocks

Metamorphic rocks make up about 27% of the total in the crust. Rocks of Pre-Sinian age are mostly metamorphic; many of younger age have been metamorphosed, too, for various causes.

Metamorphic rocks come from igneous and sedimentary rocks. When igneous and sedimentary rocks are buried at depth, they are baked and heated by intruding hot magma and their mineral ingredients, textures and structures undergo a series of changes under new environment characteristic of a high temperature and pressure. Metamorphic rocks are formed as a result of these changes.

Common metamorphic rocks include slate, schist, phyllite, gneiss, marble, etc. Slate is a dense, fine grained, well foliated rock which can be split into thin smooth slabs for blackboards, roofings and a number of other purposes. Gneiss is a highly metamorphic rock which has poorly developed foliation, but has a banded, streaked appearance, often granite-like. Although it can be used to build houses as well, gneiss is easy to rift in a certain direction. Marble is produced by the metamorphosis of lime-stone and similar rocks under high temperature. It differs from limestone in being visibly crystalline.

In some cases marble exhibits beautiful tints due to the presence of minor amount of black graphite, vivid-green taxoite and other minerals in it. The Chinese name for marble "Dalishi" comes from the locality name Dali, a county in Yunnan Province, where marble occurs in abundance. A special marble produced in Fangshan county, Beijing, is called "Hanbaiyu" ("white jade of the Han Dynasty") because it is white, exquisite, lustrous softly, fine grained. Columns and banisters made of "Hanbaiyu" are commonly seen for decorative purposes in the Palace Museum, Jinshuiqiao bridge, Beihai Park, the Monument to the People's Heroes and the Chairman Mao Memorial Hall. The famous Danbi, a flight of steps, in front of Taihe Temple in the Palace Museum, is carved out of "Hanbaiyu" (Fig. 40).

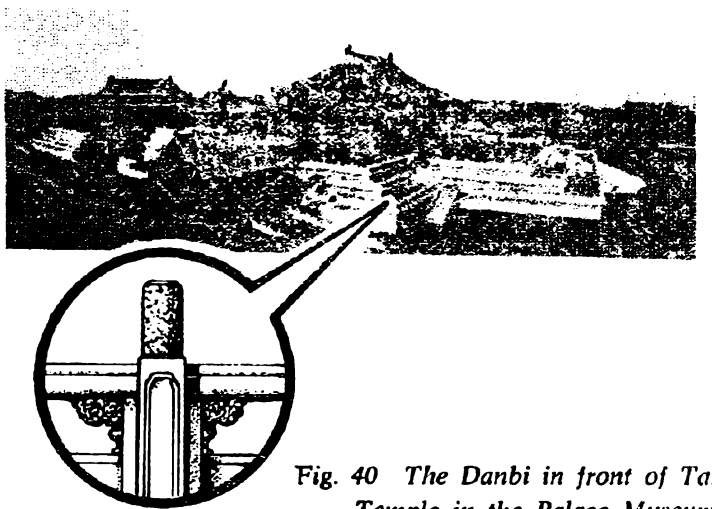


Fig. 40 The Danbi in front of Taihe Temple in the Palace Museum

A special record of the earth's history

Remains or traces left by animals or plants of the past in sedimentary rocks are known as fossils, such as gigantic skeletons of dinosaurs mounted in natural history museums, insects embedded in amber, siliceous wood displayed in geological museums (Fig. 41), the "Peking Man" skulls excavated from the limestone cave deposits of Zhou-Kou-Dian, Beijing, etc.

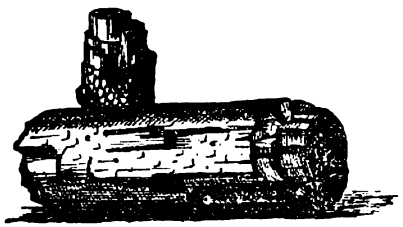


Fig. 41 Siliceous wood

How do animals or plants become fossils? Do all organisms change into fossils after they die? The answer is no because petrification or "fossilization" of animals and plants depends on a number of conditions. Generally two important conditions are indispensable. First, the organisms themselves must have skeletons, shells and the like which are hard enough not to decay easily; second, rapid burying of the dead animals or plants is required to isolate the remains from air, or else they will be oxidized and decomposed. Even the hard parts of their bodies cannot bear the gnawing of sun rays. wind, water currents, rain, etc. Therefore only those lying at a suit-

able site such as river mouth, lake basin or shallow sea, where rapid burying is available, have the opportunity to be preserved as fossils. Sometimes an organism can be completely preserved under a special condition as an insect is caught by fluid resin and later turned into amber. Somewhere on the earth flurished pines, herbs and flowers, 40 million years ago. Among them insects were flying. At a time an insect was suddenly glued and wrapped by resin dropped from pine trunk. Then buried by sand and mud and undergoing a series of geological changes, the resin drop changed into amber, in which the little insect was fossilized (Fig. 42).

Fig. 42 Fossil insect in amber

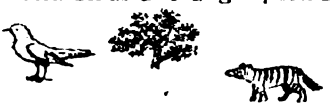
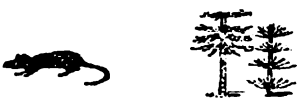
Strata containing fossils are just like a book that tells us the story of the earth and the evolutionary history of living things, and also presents us with scientific data for study of paleontology, paleogeography and paleoclimatology.

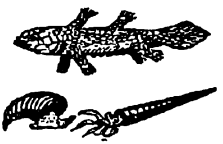
However in some cases we may take pseudofossil as fossil. On joint planes of stratum we often see some thin films which look extremely like cypress twigs and therefore pass for fossils. In fact, they are simply manganese and iron elements brought in cracks by underground water and deposited there. At the foot of the Great Wall at Badaling, someone paid for

this pseudofossils as a sightseeing keepsake of the Great Wall. We can find trunk-like things displayed in some temples in the depth of mountains. People call them petrified wood. As a matter of fact, some of them are, but some of them are not petrified wood.

It is known that organisms evolve generally from very simple to complex. Thus the older the strata are, the fewer and the more simple the fossils in the strata are; in the oldest strata even no trace of fossils has been found. On the other hand, the younger the strata are, the greater the number of fossils is and the more complex the fossils are. Therefore fossils are used to estimate the relative age of strata as well as to understand the evolutionary history of organisms. Two hundred years' study of the fossils excavated from sedimentary rocks gives us evidences of evolution of organism. Several evolutionary stages are distinguished. Based chiefly on the stages five divisions of geological time, called eras, are made: Archeozoic era, Proterozoic era, Paleozoic era, Mesozoic era and Cenozic era. Further subdivisions of each of the eras into briefer units of time are called periods. We arrange the eras and periods in a list from bottom to top corresponding to strata from old to young, to indicate the ages of rocks. Such a list is the geological time scale, see table below.

We get in the table the relative age of the corresponding strata in a certain era and the representatives of animals and plants appearing in a relevant era, and if these representatives, called "guide fossils", are found in a certain bed in turn, then its relative age can be inferred.

Era	Period	Years before present (M. y.)	Some important events in the history of life
CENOZOIC	Quaternary	2-3	Man
	Neogene	25	
	Paleogene	70	Expansions of mammals and birds and angiosperms 
MESOZOIC	Cretaceous	135	First flowering plants; last dinosaurs
	Jurassic	180	First birds, dinosaurs and gymnosperm abundant
	Triassic	225	First mammals, abundant cycads and conifers 

PALEOZOIC	Permian		Great expansion of primitive reptiles
		280	
	Carboniferous		First reptiles, amphibians abundant
		350	
	Devonian		First amphibians, fishes abundant
		400	
	Silurian		First land plants
		440	
	Ordovician		First fishes, nautilus abundant 
		500	
	Cambrian		Trilobites dominant
		600	
	Proterozoic		Primitive algae abundant, first eucaryote
		2500	
	Archaeozoic		First procaryotes
		4600	

For a long time in the past, geologists determine the succession of strata of different ages from the principle of superposition which states that in a sequence of nomal layered rocks, the oldest bed is at the bottom, with successively younger beds lying above, and judged the relations of geological events from principle of crosscutting relations which says that an igneous rock is younger than any other units it affects, and finally inferred their geological ages by using fossils contained in the intruded sedimentary rocks.

Since the 1940's, rapid development of science and technology has made it possible to measure "absolute age" of rock by examining radioactive isotope in the rocks, so "absolute age", in other words, is "isotopic age". The known geological age of the earth at present is about 4.6 billion years. The oldest record of life known up to now is the 3.2 billion years old microfossils — *Eobacterium isolatum*, the "isolated dawn bacteria" (seen under electron microscope) found in South Africa. Strictly speaking, organisms came into flourish and rapid development merely 0.6 billion years ago. It was not until 2-3 million years ago that the ancestor of human being appeared on the earth. The time span seems to be very long in comparison with human's recorded history, but it is only a twinkle in the long history of the earth.

Fossils also indicate the ancient environment in which the animals or plants lived. Animals and plants require particular environments favorable for them to live in. Changes in geographic conditions resulted and are resulting in mortality or migration of animals and plants. In 1964 a Chinese exploring team discovered gigantic animal fossils — ichthyosaur

(Fig. 43), which once dominated the ancient sea, in strata of Late Triassic Period at an altitude of 4,300m in Mount Xixiabangma, Tibet. The discovery evidences that the area where stand the snowy, spectacular Himalayas today was a vast sea extending west-east. At the same time the team also found at an altitude of 5,900m a fossil mountain oak (*Quercus semicdrpifolid* sm), which now lives at an altitude of only 2,500—2,700m in the mountains of western Sichuan. This finding implies that Mount Xixiabangma was at an altitude of 2,700m at that time when the plant was buried. Since then the mount rose by about 3,200m within 3—4 million years. It was described in Chinese historical books that "shells have been seen in stones in high mountain, meaning the changes of fields." It is thus clear that fossils are the "telling witness" to the vicissitudes of sea and land (Fig. 44).

In addition, fossils tell us something about ancient climate. Coral, for example, a marine animal, lives in warm shallow sea (average temperature 18°—20°C, depth less than 100m). If coral fossils are found in limestone strata, we can infer that here was a warm, shallow sea in a certain geological period. Ostrich egg shells have been found in loess dated hundreds thousand years ago and distributed throughout North China, which indicates that the climate of North China was once hot and dry. We have found remains of elephant, rhinoceros, tapir, David's deer, deer, buffalo, buried in Yin Dynasty ruins in Henan Province. It must be considered that climate in Henan in the Yin Dynasty, about 3,500 years ago, is much hotter and wetter than that of today.

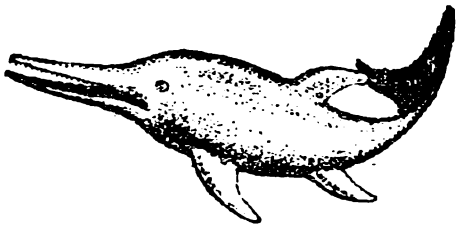


Fig. 43 Ichthyosaur found in Himalayas

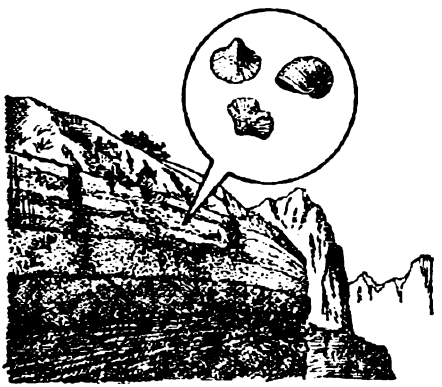


Fig. 44 Marine invertebrate fossils discovered in Taihang mountains

We come to the conclusion from the foregoing examples that fossils not only indicate ancient environments and climate in a certain place at a certain time but also tell us the vicissitudes of sea and land. In the light of what we learn from fossils we can draw several kinds of paleogeographic maps (Fig. 45).

Fig. 45 Distribution of sea and land of Triassic Period in China (lines: ingression areas; white: land)

Besides, fossils serve as clues to ore-exploring. For instance, a coal mine in Jiangsu Province had been considered to be exhausted, for someone thought the lowest coal bed had been mined. However thanks to the finding of fossil proto-

zoan — fusulinid, which lived in ancient shallow sea (Fig. 46), it was made sure that the top bed had been mistaken for lowest one in the coal series. Further exploration revealed the underlying rich coal beds.

a *b*

Fig. 46 Extinct protozoan — fusulinid (Enlarged)
a - thin section; b - Test of fusulinid

CHAPTER V

TREASURES IN THE EARTH—MINERAL RESOURCES

Mineral resources are treasures in the earth. Everybody knows the important roles they play in human's daily life and national economy. Imagine what human life would be like if we had no iron and steel to support our factories in the modern society, no oil and coal to warm our houses!

Abundance of mineral resources

Mineral resources are the valuable minerals or rocks in the crust that are presently recoverable or may be so in the future. The naturally occurring material digged out from the ground, from which a mineral, or minerals, of economic value can be extracted, is called ore.

Mineral resources in the earth are many and varied. Based on their properties and industrial uses, they are divided into several kinds as follows.

i. Metalliferous ores

Ferrous metals: iron, manganese, chromium, vanadium, titanium (major raw materials for iron and steel industry).

Nonferrous metals: copper, lead, zinc, tungsten, tin, molybdenum, antimony, mercury, bismuth, aluminium, magnesium, cobalt, nickel, etc.

Rare metals: lithium, beryllium, tantalum, niobium, rubidium, cesium, strontium, etc.

Noble metals: gold, silver, platinum.

Rare-earth metals: neodymium, samarium, ytterbium, etc.

Radioactive metals: uranium, radium, thorium.

ii. Nonmetalliferous ores

Auxiliary raw materials for metallurgical industry: magnesite, refractory-clay, quartzite or silicarenite, fluorite, limestone, dolomite, etc.

Raw materials for manufacturing chemical fertilizer and pesticide: arsenic (realgar, orpiment), phosphorus, potassium, nitrogen.

Raw materials for chemical industry: sulphur, phosphorus, sylvite, salt, natural alkali, alumstone, mirabilite, barite.

Raw materials for fuel industry: coal, oil shale, petroleum, natural gas.

Raw materials for electrical equipments: mica, andalusite, piezoelectric quartz, graphite, asbestos, etc.

Building materials: feldspar, quartz, clay, kaolin, asbestos, gypsum, talcum, limestone, quartz sand, diabase, basalt, pumice, diatomaceous earth, sandstone, psephyte, etc.

Raw materials for arts and crafts: agate, crystal, and other gems and jades.

China flows with mineral resources. About 140 kinds

of minerals explored and used now in the world have been known to occur in China. Among them reserves of 132 minerals have been roughly ascertained. Especially reserves of tungsten, tin, antimony, zinc, bismuth, hold the first position and those of coal, oil, iron, copper, aluminium, phosphorus are among the most in the world.

China is also rich in energy sources. Magma transmits tremendous heat energy to strata when it moves there. The strata, like heaters, heat the groundwater in them. From the heated water we get the geothermal energy, which seems to promise an endless supply of energy (Fig. 47). Geothermal sources are widely distributed in China, especially in Tibet, Yunnan, Fujian, Guangdong and Taiwan. Along the Yalu-

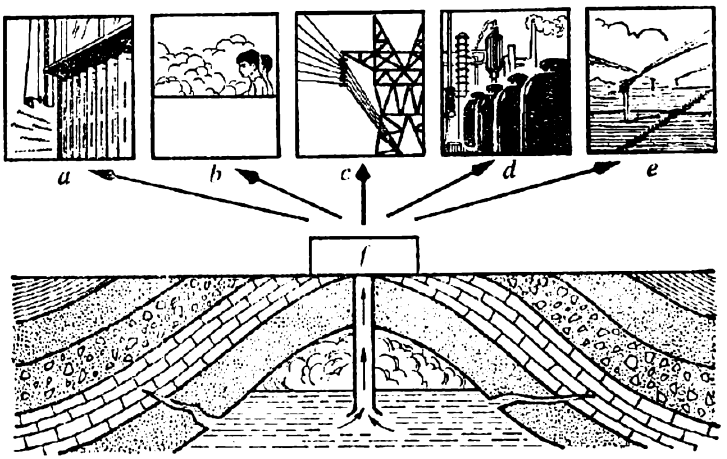


Fig. 47 Uses of hot groundwater

a-Heating; b-Medical treatment; c-Generating electricity; d-Industrial raw materials; e-Irrigation; f-Hot subsurface water

zangbujiang river that is the Himalayas geothermal zone are the areas where geothermal sources are abundant. Almost in every county adjacent to Lasa geothermal sources have been discovered. Geothermal action usually manifests itself in hot spring, boiling spring, geyser and water shooting. Water in some boiling springs in Tibet are on the boil and steam is gushing, whistling, out of the springs, like steam boxes. When a geyser is spurting, steam rises to form a column ten to twenty meters high which shoots into the sky with a rolling steam ball at its top. Water shooting is a more fierce geothermal action. When it bang explodes, like a volcano in eruption, water and steam, mixed together with mud, sand and stone, spurt straight up into the air.

China has been noted for its "vast territory and abundant resources" since ancient times. Rich mineral resources provide the material base for national economic development. From the days when Peking Man chipped his stone tools to the time when pottery appeared towards the end of primitive society of lithic age; from the Bronze Age of slave society to the Iron Age of feudal society, mineral resources have marked their merits in every page of human history. They also have wide applications, say, to food processing and even to medicine. Today we live in the atomic age in which alloy products, compound materials and engineering plastics are commonly used. As a result, a tremendous amount of mineral resources is required. Thus the exploration and exploitation of mineral resources seem to be even more important today than they used to be.

Usually useful mineral exists in certain rocks that favor

it. Magma containing complex metallic elements and other minerals intrudes into the earth's crust to form igneous rocks. During the process metallic elements with different melting points and specific gravities, interacting with wall rocks, respectively and successively crystallize or combine to form metalliferous ores under complex geological conditions. In general, heavy metals, such as platinum, chromium, nickel, diamond, are found in periodotite; many nonferrous metals such as copper, lead, zinc and noble metals, rare metals and radioactive metals in granite and in its contact zone; coal, oil, bauxite, iron, manganese, phosphorus, rock salt, gypsum, etc. in sedimentary rocks; whereas asbestos, graphite, talcum, etc. in metamorphic rocks, and so on. It is clear that the formation and distribution of ore deposits are bound up with rocks, exogenic and endogenic forces. The identification of rocks and the study of their geological structures will well benefit exploitation and utilization of mineral resource.

Plant and coal

As a fuel, coal is familiar to people. It comes from the plants of the past (Fig. 48). Fossil plants, including roots, trunks, branches, leave and fruits, are often found in coals and surrounding rocks. Tissues and structures of original wood are observed in thin section of coal under a microscope. Besides, coal and plant have essentially similar chemical composition, both are composed of carbon, hydrogen, oxygen, nitrogen, sulphur and other elements. All these bring home to us that coal is from ancient plants.

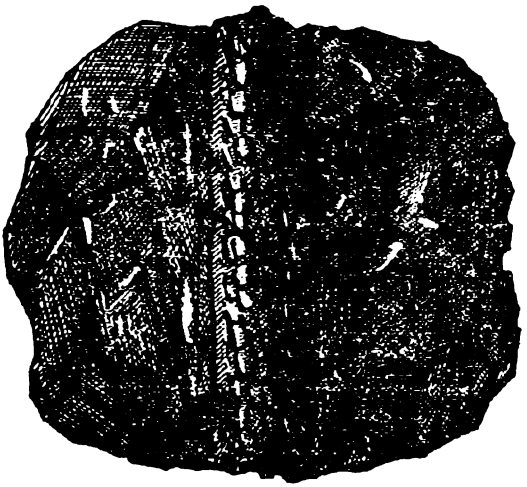


Fig. 48 Root of ancient tree became coal

How did plant change into coal? During certain geological periods warm and wet climate favored plants to grow on some parts of the earth's surface such as lakes, swamps and littoral areas. When the plants died, they would be washed into lakes or shallow sea where they accumulated and were buried by mud and sand. Under the condition short of oxygen, plants were decomposed by bacteria and turned into peat or jelly-like sapropel which consisted of plant remains.

Peat and sapropel buried would let out a great amount of water and volatile components (N, O, S, etc.), and with the decrease in their volume and increase in hardness, they

changed into brown coal. Temperature and pressure will go up continuously if the burying depth of brown coal became greater as the crust sank and if the overlying strata were thickened. When water and volatile components kept losing and carbon content and hardness increased to a even greater degree, brown coal was transformed into soot, and further into hard coal.

Owing to the increase of pressure, carbonization went on. As carbon content augmented and volatile dwindled, color of coal became much blacker and the heat value got higher. In the process of carbonization coal got harder and more lustrous when changing from brown coal to hard coal. Therefore coals are quite different in property and of course are used for various purposes.

Brown coal: lignite. A low-rank coal which is brown, or brownish black, lusterless, light and loose in texture, and commonly manifesting the structure of original wood. It is low in heat value and smokes densely on burning due to its high content of moisture. Lignite is an important raw material for chemical industry or for refining oil, and also used as the chief fuel coal for industry purpose in some countries that are lack of soot.

Soot: It is black, dense, less lustrous, smoking when burning, surface smooth, higher heat value. As a good fuel for generating electricity and steam heat boilers and coking, it serves as the chief fuel coal for industry.

Hard coal: It is pitch-black, hard but crisp, lustrous and dense. Containing little volatile, it is less used in industry, say, in coking. Nevertheless, it is a good fuel for cooking-

stoves in kitchens or a raw material for gas generating on account of its high heat value. It smokes less but lasts a relatively long time when burning.

As coal comes from ancient plants depositing in lakes or brackish water lagoon, it goes without saying that coal beds are embedded in sedimentary rocks (sandstone, shale, psephyte, for example). The "roof" or rock bed immediately overlying a coal bed is apical plate, and that underlying coal bed is lying plate. The preserved part of a coal-series formed in a given geological period after tectonic movement, extending tens or hundreds of km^2, is known as a coal field. Coal fields mostly occur in strata of Carboniferous Period (350 — 225 m.y. ago), of Jurassic Period (180 — 135 m.y. ago), and of Tertiary Period (70 — 2 m.y. ago). China is among the richest in coal resource in the world and important coal fields are found throughout the country, especially in North and Northwest China.

Organisms and oil

Petroleum is a kind of "fossil fuel" in liquid state, often occurring in association with natural gas.

Kerosene oil used to light kerosene lamps and stoves, gasoline to drive our cars and planes, lubricant to relax machines, vaseline and paraffin wax to benefit patients, pitch to smooth roads, are all extracted from petroleum. In addition, at least five thousand petroleum products are extensively used in all fields of industry, agriculture and military.

Now we shall ask what petroleum really is and where it comes from?

Petroleum is a natural occurring complex liquid hydrocarbon that may contain varying amount of impurities, so as to tint its color variably from brownish-black to brownish-yellow. It is a thick oily liquid, lighter than water, and combustible.

Petroleum comes from organisms of the past. In geological time large number of animals, plants and especially microorganisms thrived in water of bays, shallow seas, or lakes where they, when died, would deposit together with clay, silt and sand, to form organic mud and ooze. Clay and sand deposited continuously and finally closed the organic ooze. Under a combined action of anaerobe, temperature and pressure, organisms turned into oil through a series of complex changes. Initially oil is just drops scattering in source beds. The oil drops were gathered by pressure into permeable reservoir rocks (such as sandstone, psephyte, limestone) in which innumerable holes and cracks exist. Since oil is lighter than water, it tends to move upward through openings and cracks until it encounters impervious beds. If a impervious bed occurs above the reservoir beds to prevent oil from penetrating upwards, oil may then accumulate beneath the impervious layer. Antilines are the most favorable structures to house oil, and such a structure to hold or trap oil is called reservoir structure. Reservoir structure and sedimentary rocks of lacustrine facies or shallow sea facies are guides to geologists in exploring oil and natural gas (Fig. 49).

China is the first country in the world where the value

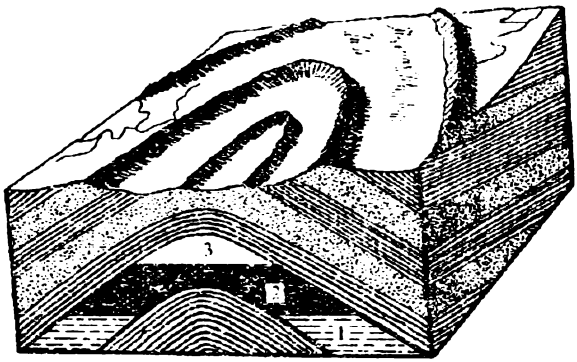
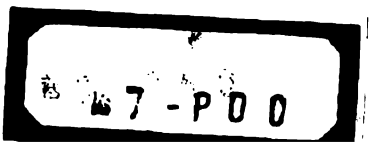


Fig. 49 Reservoir structure for oil
1-Water; 2-Oil; 3-Gas

of oil was recognized and oil was utilized. Account about oil was recorded in "The Book of Changes", a work written in Zhou Dynasty, about three thousand years ago. In Eastern Han Dynasty about two thousand years ago, Chinese already knew that oil could burn well but was not "edible". They scooped up the "oil film" floating on water surface, and used it as lamp oil. In the last years of Zhengde in Ming Dynasty (in 1521), Chinese people had drilled a 1,000-meter-deep well to exploit oil and saline in the Jianwei district, Sichuan Province. The well is 300 years earlier than the famous "Drake's well" (1859) in the United States, and is much deeper than the latter (at a depth of 21.69 m). Shen-kuo, a famous scholar of Northern Song Dynasty, when he saw people lit the black liquid running out from sandstone, first called it "stone oil", meaning oil coming from stone.

However, it was almost utterly in the dark about these

precious mineral resources in old China. Someone had alleged "China was poor in oil". In 1959, however, Chinese scientists and workers, after investigation and exploration, discovered and exploited Daqing oil field, and afterwards, Shengli oil field and the North China oil field were discovered. The more important fact is that oil has been found in the three huge settling zones in east China, i.e., Shan-Gan-Ning and Sichuan basin zone, Song-liao plains, north China plain (including Bohai), Jiang-han plain and Gulf of Tonkin zone, and Yellow Sea, East China Sea, and South China Sea zone. Exploitation of these areas will greatly speed up the four modernizations in China.



科学普及小丛书
地壳
谢淇诚 著
刘静媛
孟津 译
责任编辑 英民
封面设计 胡焕然
中国科学技术出版社出版
（北京西郊白石桥路32号）
中国国际图书贸易总公司总发行
（北京399信箱）
1986年9月第一版
1986年9月第一次印刷
编号：（英）13051—1419
00105.
13—E—1863 P